

Geospatial Analysis of Land Use and Land Cover Change: A Case Study of catchment area of Ramganga river, Uttarakhand

Aprajit Puri

Independent Researcher

DOI: 10.64823/ijter.2604012

© 2026 *The Author(s)*. Published by *Ambesys Publications*. This is an open-access article distributed under the terms of **Creative Commons Attribution License (CC BY 4.0)** (<https://creativecommons.org/licenses/by/4.0/>)

Abstract: In the last ten years, the Kaladhungi area of Nainital district has undergone notable changes in land use influenced by socio-economic, environmental, and institutional elements. Historically focused on agriculture, the area is now experiencing a slow transition to non-agricultural pursuits, such as industrial growth and fruit tree farming. Diminishing interest from young people, shortages in labour, and heightened susceptibility to climate fluctuations have diminished the sustainability of conventional farming methods. As a result, numerous farmers are transforming farmland into orchards or selling it for commercial use, pursuing greater financial gains and less reliance on labour.

Simultaneously, agricultural producers encounter various obstacles, including water shortages, conflicts with wildlife, soil deterioration, scattered land ownership, and restricted market opportunities, which all threaten the sustainability of farming. Policy measures, such as land reform rules and environmental safeguards, aim to manage land conversion and maintain ecological balance; nonetheless, gaps in implementation remain. Local governments, using a multi-level governance structure, are essential in overseeing land use changes, balancing progress with ecological preservation.

The research underscores that the current transition from agriculture to other land uses signifies a wider rural change, raising worries about the sustainability of agriculture and livelihood security over time in the Himalayan area

Keywords: *Land Use and Land Cover (LULC) Change, Agricultural Transformation, Himalayan Region, Socio-Economic Drivers*

I. INTRODUCTION

Changes in land use and land cover (LULC) have become a vital field of study for comprehending the relationship between human actions and environmental systems, especially in ecologically sensitive areas like the Himalayan foothills (Lambin et al., 2003). Mountain areas are exceptionally responsive to human-induced pressures and climate fluctuations, rendering them especially susceptible to unsustainable land changes (Negi et al., 2017). In the context of the Indian Himalayas, swift socio-economic changes in recent decades have notably transformed conventional land use patterns, particularly in regions like Uttarakhand (Rawat & Kumar, 2015).

Traditionally, the rural economies in Uttarakhand were mainly based on agriculture, featuring subsistence farming, minimal mechanization, and restricted livelihood diversification (Jodha, 2005). Nonetheless, from the early 21st century onward, structural changes fuelled by rising literacy, migration from rural to urban areas, and market integration have resulted in a slow decrease in reliance on agriculture (Rigg, 2006). In areas like Kaladhungi in Nainital district, these transformations are becoming more evident through reduced

agricultural operations, the repurposing of farmland for non-agricultural purposes, and the rise of different land use practices including orchards and small industries.

The conversion of farmland is not just an economic issue but is also strongly connected to various environmental and institutional elements. Farmers in the area encounter various challenges, such as water shortages, soil erosion, small land parcels, and restricted availability of markets and advanced agricultural technologies (Pingali, 2012; Birthal et al., 2014). Moreover, the area's closeness to wooded areas escalates conflicts between humans and wildlife, thereby diminishing agricultural viability (Negi et al., 2017). Climate fluctuations, shown through unpredictable rainfall and severe weather occurrences, heighten production risks and lead to agricultural hardship.

II. STUDY REGION

The Kaladhungi- Bealparao region lies in Nainital district of Uttarakhand state Kaladhungi at Coordinates 29° 17' 0.636" N & 79° 21' 3.6" E. It is well situated in the catchment area of river Koshi. The Kosi River, a significant geographical feature, forms a natural boundary between Nainital and Almora districts before merging with the Ramganga River flows through this region, and the region is well irrigated by these rivers. The region is rich in agriculture and orchards. Although there is an increasing amount of literature concerning land use change in the Himalayan area, there is still a notable scarcity of micro-level, field studies that combine local perspectives with wider institutional and environmental contexts. Specifically, little focus has been directed towards transitional areas like Kaladhungi, where farming landscapes are quickly changing due to the joint effects of economic hopes, environmental challenges, and policy actions.

III. OBJECTIVES

To examine the degree and trends of land use and land cover (LULC) alterations in the Kaladhungi area during the last ten years.

To discern the main socio-economic and environmental factors driving the transition from conventional agriculture to alternative land uses, such as orchards and non-agricultural pursuits.

To identify the key challenges encountered by farmers and examine how institutional and policy frameworks influence sustainable land use strategies

IV. LITERATURE REVIEW

Alterations in land use and land cover (LULC) are widely acknowledged as significant indicators of the interactions between human actions and environmental systems, especially in ecologically sensitive areas like the Himalayan foothills (Lambin et al., 2003). Mountain ecosystems are particularly sensitive to human-induced pressures and changes in climate, rendering them susceptible to unsustainable alterations in land use (Negi et al., 2017). In the context of the Indian Himalayas, research has recorded notable changes in conventional land use practices resulting from swift socio-economic changes, particularly in Uttarakhand (Rawat & Kumar, 2015).

Traditionally, the rural economies in Uttarakhand were mainly agricultural, defined by subsistence farming and minimal livelihood diversification (Jodha, 2005). Nevertheless, enhancing literacy, migration from rural to urban areas, and market integration have slowly diminished reliance on agriculture (Rigg, 2006). This has led to the transformation of farmland into different uses like orchards, urban developments, and small manufacturing.

V. RESEARCH METHODOLOGY

This research employs a combined geospatial and field-based method to examine land use and land cover (LULC) alterations in the Kaladhungi area of Nainital district, Uttarakhand. Data sources from both secondary

(satellite-based) and primary (field-collected) origins were employed to guarantee methodological precision and validation of results.

VI. DATA ORIGINS

The basis of spatial analysis was multi-temporal satellite imagery. Landsat datasets, comprising Landsat 5 (TM), Landsat 7 (ETM+), and Landsat 8 (OLI/TIRS), were selected for their reliable temporal coverage and 30-meter spatial resolution, making them appropriate for regional LULC research. Satellite images from various time points in the past decade were chosen to reflect temporal changes. Moreover, RESOURCESAT imagery was utilized to improve classification precision and cross-validation.

Primary data were gathered via field surveys and semi-structured interviews with local residents, including farmers and older community members, to comprehend on-the-ground changes, socio-economic factors, and views on land use transformation.

VII. IMAGE ANALYSIS AND CATEGORIZATION

The satellite images went through typical pre-processing procedures, such as geometric correction, radiometric correction, and atmospheric normalization to guarantee consistency across different time frames. LULC classification was conducted through a supervised classification method, utilizing training samples obtained from field observations and high-resolution reference data. Key land use categories recognized consisted of agricultural land, orchards, forested areas, urban regions, and wasteland. Accuracy evaluation was conducted using ground truth data and confusion matrix analysis to assess the dependability of classification.

VIII. ANALYSIS OF DATA

Temporal variations in land use were measured through change detection methods, allowing for the recognition of shifts among various land use types. Spatial analysis utilized Geographic Information System (GIS) tools to map and illustrate LULC changes.

Data derived from interviews were examined through thematic analysis to uncover repetitive themes concerning agricultural decline, workforce shortages, land usage changes, and environmental issues. These insights were utilized to enhance and elucidate the geospatial results.

IX. LIMITATIONS

The research is constrained by the spatial resolution of satellite imagery and the presence of cloud-free images for certain time frames. Moreover, field observations are limited by the size of the sample and the subjectivity of respondents; nonetheless, measures were taken to guarantee reliability via cross-verification

Fig. 1.1 Landsat Images of Kaladhungi region

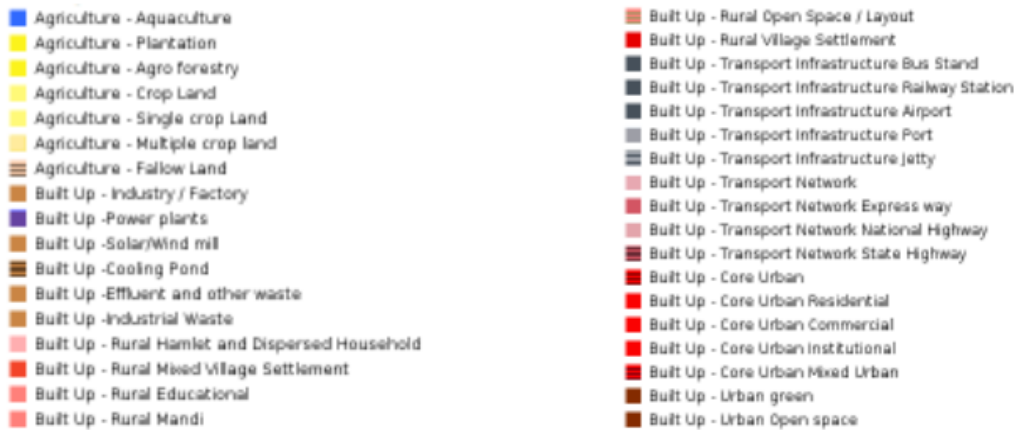
LULC Kaladhungi Bealparao region (2015-16)



LULC Kaladhungi Bealparao region (2023)



Fig 1.2 Legend



- **Adoption of Modern Agricultural Practices:** The introduction of modern equipment, such as tractors, has transformed farming, reducing physical demands on landowners and farmers.
- **Labor Shortages:** A scarcity of laborers during harvest seasons has led to delays, with crops often damaged by unseasonal rains, hailstorms, or other weather events before harvesting.
- **Youth Disinterest in Farming:** Higher literacy rates and access to alternative job opportunities have reduced interest in agriculture among younger generations, who prefer less labor-intensive, higher-paying jobs.
- **Conversion to Non-Agricultural Uses:** Agricultural lands are increasingly being converted into factories and small-scale industries for profit maximization. Farmers sell their land for financial gain and perceived development benefits.
- These insights underscore the rapid shift from agricultural to non-agricultural land use, driven by socio-economic and environmental factors, impacting the region's agricultural sustainability.

Fig 1.3 (Factories)



Fig 1.4 (New Orchards)



Fig 1.5 (Small landholdings)



Orchards as an Alternative to Agricultural Practices

In recent years, farmers in Nainital district have increasingly shifted from traditional agricultural practices to establishing orchards, a trend that has gained significant momentum over the past decade. Many farmlands have been converted into orchards, reflecting a significant transformation in land use patterns.

X. BENEFITS OF ORCHARDS COMPARED TO AGRICULTURAL TRACTS

1. **Economic Viability:** Orchards offer greater financial returns compared to traditional agricultural fields, making them a more economically attractive option for landowners seeking to maximize profits.
2. **Reduced Maintenance Requirements:** Unlike agricultural fields, which require consistent upkeep, orchards demand less maintenance once trees are established. This lower maintenance burden makes orchards a practical alternative for landowners.

3. **Lower Labor Dependence:** Orchards require fewer laborers, addressing a critical challenge faced by traditional agriculture, where labor shortages during harvest seasons often lead to delays and crop losses due to unseasonal rains or hailstorms. The reduced need for labor makes orchards an appealing option for farmers.
4. **Leasing Opportunities:** Many landowners lease their orchards to interested parties through 11-month legal contracts, transferring maintenance responsibilities to the lessee. This arrangement relieves landowners of ongoing obligations, providing financial benefits without the burdens of direct management.

Main challenges faced by the farmers in this region Farmers in Kaladhungi, located in Nainital district, Uttarakhand, encounter numerous obstacles due to the region's unique geographical, climatic, and socio-economic conditions. The primary challenges are outlined below.

1. **Water Scarcity and Irrigation Constraints**

Agriculture in Kaladhungi heavily relies on rainfall, making it vulnerable to irregular monsoons or insufficient precipitation, which can significantly reduce crop yields. Recent diversions of local canals to the Kotabagh region have further decreased water availability compared to previous years. Limited irrigation infrastructure, such as canals or tube wells, exacerbates dependence on seasonal rains, while fluctuating groundwater levels add to the challenge.
2. **Human-Wildlife Conflict**

Proximity to Jim Corbett National Park results in frequent crop damage by wildlife, including wild boars, elephants, and monkeys. Additionally, livestock face threats from predators like leopards and tigers, leading to substantial economic losses for farmers.
3. **Soil Degradation and Erosion**

Soil erosion is a significant issue on sloped terrains, worsened by deforestation and unsustainable land use practices. Over-reliance on chemical fertilizers has also contributed to declining soil fertility, posing challenges to sustained agricultural productivity.
4. **Limited Access to Modern Agricultural Practices**

Many farmers depend on traditional farming techniques and lack exposure to advanced agricultural methods or innovations. Access to extension services and training programs is often limited, particularly for smallholder farmers in remote areas.
5. **Market Access and Pricing Issues**

Farmers face difficulties reaching markets, often relying on intermediaries who purchase produce at low prices. Poor road connectivity and the absence of cold storage facilities lead to significant post-harvest losses, especially for perishable crops.
6. **Small and Fragmented Landholdings**

Land fragmentation, resulting in small and scattered plots, hinders efficient mechanized farming and limits crop diversification (see Figures 4.12 and 4.13). These small landholdings reduce potential income and make farming less economically viable.
7. **Climate Variability and Natural Disasters**

The region is susceptible to climate-related challenges, including unseasonal rainfall, hailstorms, and droughts. These unpredictable weather events can devastate crops, threatening agricultural output and farmer livelihoods.
8. **Labor Shortages Due to Migration**

Limited economic opportunities in agriculture drive young people to migrate to urban areas, resulting

in a shortage of farm labor. This leaves an aging population to manage agricultural activities, further reducing productivity.

9. **Insufficient Financial Support**

Farmers often face challenges accessing credit, insurance, or government subsidies. Bureaucratic complexities and lack of awareness prevent many from benefiting from agricultural support programs designed to enhance resilience and productivity.

Policies or Regulations govern land use in this area The Uttarakhand (Uttar Pradesh Zamindari Abolition and Land Reforms) Act, 2012, establishes restrictions on land ownership and conversion in Uttarakhand. A significant amendment, passed on February 19, 2025, tightened these regulations, prohibiting non-residents from purchasing agricultural or horticultural land in 11 of the state's 13 hill districts, including Nainital, which encompasses Kaladhungi. This amendment revokes the authority of district magistrates to approve land transactions, centralizing oversight through a digital platform that requires affidavits and detailed reporting to ensure transparency and compliance. These measures aim to protect local agricultural resources and cultural heritage by limiting external land acquisition.

City Development and Construction Regulations

Land use in Kaladhungi is governed by regional frameworks, such as the Nainital Master Plan and the District Development Authority. Since the 1930s, with updates in 1992, construction regulations have prohibited building on geologically unstable areas, particularly steep slopes prone to landslides. The Special Area Development Authority (SADA) of Nainital oversees building permits, enforcing strict restrictions on approximately 1.6 km² of designated high-risk zones. However, enforcement remains inconsistent, posing challenges to sustainable development.

High Court Orders and Environmentally Sensitive Areas

The Uttarakhand High Court has imposed stringent environmental protections to safeguard ecologically sensitive zones:

- A 2 km no-construction zone around major lakes, including Nainital, Bhimtal, Khurpatal, Sattal, and Naukuchiatal.
- A 5 km ban on tree cutting surrounding these lakes to preserve forest cover.
- A 25 km construction-free buffer around glaciers, supplemented by prohibitions on fossil fuel use within 10 km and plastic use within 20 km.

Several hill towns, including Nainital, are designated as eco-sensitive zones, subject to enhanced environmental scrutiny to mitigate ecological degradation.

Environmental Infrastructure and Water Resource Management

The District Environment Plan for Nainital emphasizes sustainable land use practices to manage water resources effectively. Initiatives include promoting artificial groundwater recharge, rainwater harvesting, check dams, and contour trenches to enhance water availability. In Kaladhungi, an 8.2 km canal project (from Panchakki to Kamaluwaganja) has been approved to improve drainage, facilitate road expansion, and reduce urban congestion, supporting both environmental and infrastructural development.

XI. CONCLUSION

This research uncovers notable changes in land use and land cover (LULC) in the Kaladhungi area over the last ten years, characterized by a transition from conventional farming to orchards and non-agricultural

applications. Labourer shortages, youth migration, shifting livelihood preferences, and rising climate-related risks are propelling these transformations. Farmers encounter various difficulties, such as limited water supply, conflicts with wildlife, and decreasing soil fertility, which have diminished the effectiveness of traditional agriculture. Despite the existence of policy frameworks to manage land use, shortcomings in implementation hinder their efficiency. The results also underscore a continuous rural shift and stress the importance of cohesive approaches to encourage sustainable farming, enhance institutional backing, and guarantee long-term livelihood stability in the area. To tackle these challenges, policy measures should focus on enhancing irrigation infrastructure, fostering climate-resilient and low-labourer farming methods, and increasing market access along with cold storage options. Focused assistance via credit, insurance, and extension services is crucial for improving farm sustainability. Moreover, enhanced enforcement of land use policies and improved collaboration among local agencies are needed to address unintended land conversion. A cohesive, region-focused policy strategy is essential to harmonize development with environmental sustainability and to ensure enduring rural livelihoods in the Himalayan foothills.

REFERENCES

- [1] Rawat, J. S., Biswas, V., & Kumar, M. (2013). Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, Nainital, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Science*, 16(1), 111–117.
- [2] Rautela, P., et al. (2014). Implications of rapid land use/land cover changes upon the environment of the area around Nainital, Uttarakhand, India. *Asian Journal of Environment and Disaster Management*, 6(1), 83–93.
- [3] Rawat, J. S., Kumar, M., & Biswas, V. (2014). Land use/cover dynamics using multi-temporal satellite imagery: A case study of Haldwani town area, Nainital, Uttarakhand, India. *International Journal of Geomatics and Geosciences*, 4(3), ISSN 0976–4380.
- [4] Wakeel, A., et al. (2005). Forest management and land use/cover changes in a typical micro-watershed in the mid-elevation zone of Central Himalaya, India. *Forest Ecology and Management*, 213(1–3), 229–242.
- [5] Sharma, E., & Xu, J. (2007). Land use, landscape management, and environmental services in Mountain Mainland Asia: Introduction. *Tropical Ecology*, 48(2), 129–136.